AD-A083 076 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/6 13/2
A REVIEW OF FABRIC USAGE IN PAVEMENTS CONSTRUCTED ON SOFT SOILS--ETC(U)
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(12) LEVEL II

A REVIEW OF FABRIC USAGE IN PAVEMENTS CONSTRUCTED ON LOW-STRENGTH SOILS

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DECEMBER 1979
FINAL REPORT

Document is available to the public through the
National Technical Information Service,
Springfield, Va. 22151

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D. C. 20591

NOTICES

19

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
18 FAA-RD-79-93		

4. Title and Subtitle	5. Report Date
6 A REVIEW OF FABRIC USAGE IN PAVEMENTS CONSTRUCTED ON SOFT SOILS	11 Dec[redacted]979
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
10 Donald M. Ladd	12 30
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
U. S. Army Engineer Waterways Experiment Station Geotechnical Laboratory P. O. Box 631, Vicksburg, Miss. 39180	11. Contract or Grant No. 15 DOT-FAA-ER-430-015
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U. S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D. C. 20591	9 Final Report. May 75 - Jun 79
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A literature review was conducted to investigate the uses of fabrics in pavements in order to determine their applicability for use in constructing airport pavements on soft soils. Presented are several theories as to how a fabric enhances the performance of a pavement when fabrics are used as a reinforcement or as a separator over soft soils. Several design methods are discussed and results of several field installations are presented. Current test methods and construction techniques are also discussed.

17. Key Words	18. Distribution Statement
Fabrics Soft soil Reinforcement Pavements	Document is available to the public through the National Technical Information Service, Springfield, Va. 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	30	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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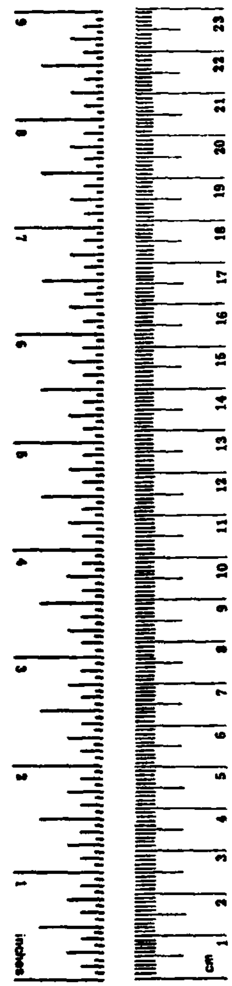
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

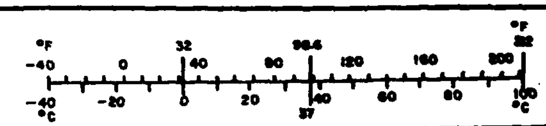
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The study reported herein was sponsored by the U. S. Department of Transportation, Federal Aviation Administration, as part of Engineering Requirement FAA-ER-430-015, "Woven and Nonwoven Fabrics in Airport Construction." Technical Monitor for this study was Mr. Fred Horn.

The study was conducted during the period May 1978-June 1979 at the U. S. Army Engineer Waterways Experiment Station (WES) by personnel of the Geotechnical Laboratory (GL) under the general supervision of Messrs. J. P. Sale and R. G. Ahlvin, Chief and Assistant Chief of the GL, respectively, and under the direct supervision of Mr. H. H. Ulery, Jr., Chief of the Pavement Design Division. This report was prepared by Mr. D. M. Ladd, Chief of the Design Criteria Branch.

Commanders and Directors of the WES during the conduct of this study were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. Fred R. Brown.

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PURPOSE AND SCOPE

For several years, studies have been made of the use of fabrics in construction of roads across soft soils. These studies have included laboratory investigations as well as prototype tests and field installations. Fabrics have proven themselves to be beneficial in increasing the life of a pavement. This improvement in performance has resulted from the fabric serving as a reinforcement, as a separator, or as a permeable soil barrier. In many instances, the required thicknesses of pavement have been reduced because of the presence of the fabric. The primary uses have been for access roads to construction sites, low-volume roads, parking lots, storage areas, railroads, etc. The purpose of this study was to investigate the uses of fabrics in pavements in order to determine their applicablility for use in constructing airport pavements on soft soils. This investigation consisted of a study of existing literature and did not involve testing of fabrics or fabric/pavement systems.

PROBLEM DEFINITION

The construction of pavements on very soft soils can create several problems. The first of these problems occurs because of mixing of the soft subgrade material with the granular base or subbase material. This mixing may occur as a result of loads applied to the pavement surface forcing the granular material downward into the soft subgrade or as a result of water filtrating upward into the granular material and carrying the subgrade material with it. Various types of solutions have been used to solve this problem, the most recognized of which is the use of a sand blanket or filter layer between the soft subgrade and the granular material. The second of these problems is the rutting of the pavement, which may occur as the soft soil is stressed by the loads using the pavement. This stress will cause the soft subgrade to move outward from under the load. Typical solutions to this problem have been to stabilize the subgrade with lime or cement or to increase the thickness of granular material in order to reduce the stress on the subgrade.

The placement of a permeable fabric between the soft subgrade and the granular material provides a filter to allow water but not soil to pass through it, a separator to prevent the mixing of the soft soil and the granular material, and a reinforcement to resist the development of rutting.

FABRICS

DESCRIPTION OF FABRICS

Fabrics currently used for constructing pavements are made of synthetic fibers. These fabrics are made with uniformity in production, have reasonably uniform pore sizes, and are rot and mildew resistant. Some fabrics also have significant tensile strengths; most are resistant to most chemicals and have a low water absorption. The extent to which fabrics possess these properties varies from fabric to fabric.

There are basically two types of fabrics, woven and nonwoven. The woven fabrics are manufactured using the weaving process, whereas the nonwoven fabrics are formed by bonding the fibers together using heat fusion, chemical fusion, or needle punching. The types of fibers used are polypropylene, polyethylene, polyester, polyamides, nylon, or glass.

A listing of many fabrics that could be considered for use in a pavement on soft soil is shown in Table 1. Also presented in the table are the manufacturer and the type fiber from which the fabric is made.

USES OF FABRICS

The fabrics used in pavements are considered by researchers to perform one or more of the following functions.

SEPARATOR

When a layer of granular material is placed on a soft soil, it is important to prevent the mixing of the granular material and the soft subgrade. Should mixing occur, the structure would be weakened and would require maintenance and/or placement of additional granular material to regain the needed strength. The placement of a fabric between these two layers of material prevents their becoming mixed and therefore preserves the strength of the granular layer.

Fabrics also serve as a separator to prevent the mixing of frost and nonfrost-susceptible materials. Should the frost-susceptible material intrude into the nonfrost-susceptible material, the capability of the pavement to minimize the effects of freezing would be reduced.

Table 1

Types of Fabrics

Fabric Name	Manufacturer	Type Fiber
Adva-Felt	Advance Construction Specialties P. O. Box 17212 Memphis, Tennessee 38117	Nonwoven polypropylene
Advance Type I and II	Advance Construction Specialties P. O. Box 17212 Memphis, Tennessee 38117	Woven polypropylene
Bidim	Monsanto Textiles Co. 800 North Lindbergh Blvd. St. Louis, Missouri 63166	Nonwoven polyester
Confil	International Paper Co. Lewisburg, Pennsylvania 17837	Nonwoven polyester
Enkamat	American Enka Co. Enka, North Carolina 28728	Nonwoven nylon
Fibretex	Crown Zellerbach Corp. P. O. Box 877 Camas, Washington 98607	Nonwoven polypropylene
Filter-X	Carthage Mills 124 West 66 Street Cincinnati, Ohio 45216	Woven polyeinylidene chloride
International Paper 503	International Paper Co. Lewisburg, Pennsylvania 17837	Nonwoven polypropylene

(Continued)

Table 1 (Continued)

Fabric Name	Manufacturer	Type Fiber
Lotrak	Kenross-Naue, Inc. 1329 Martingrove Road Rexdale, Ontario Canada	Woven polypropylene and nylon
Mirafi 140	Celanese Fibers Marketing Corp. P. O. Box 1414 Charlotte, North Carolina 28232	Nonwoven polypropylene and nylon
Mirafi 500X	Celanese Fibers Marketing Corp. P. O. Box 1414 Charlotte, North Carolina 28232	Woven polypropylene
Laurel Erosion Control Cloth	Laurel Plastics, Inc. 654 Madison Ave. New York, New York 10021	Woven polypropylene
Monofelt	J. P. Stevens & Co., Inc. 1185 Avenue of the Americas New York, New York 10036	Nonwoven polypropylene
Monofilter	United States Filter Corp. 3908 Colgate Houston, Texas 77017	Woven polypropylene
Netlon	Vexar Plastic Netting 16504 S. E. 31 St. Bellvue, Washington 98008	Polyethylene

(Continued)

Table 1 (Concluded)

Fabric Name	Manufacturer	Type Fiber
Nicolon	U. S. Textures 4229 Jeffrey Drive Baton Rouge, Louisiana 70816	Woven polyamide and woven polypropylene
Permealiner	Staff Industries, Inc. P. O. Box 797 Upper Montclair, New Jersey 07043	Woven polypropylene
Polyfilter	Carthage Mills 124 W. 66 Street Cincinnati, Ohio 45216	Woven polypropylene
Stabilenka	American Enka Co. Enka, North Carolina 28728	Nonwoven polyester
Supac	Phillips Fibers Corp. P. O. Box 66 Greenville, South Carolina 29602	Nonwoven entangled olefin
Terrafix	Kenross-Naue, Inc. 1329 Martingrove Road Rexdale, Ontario Canada	Nonwoven polypropylene with woven nylon reinforcement
Typar	E. I. DuPont de Nemcurs & Co. 1008 Market Street Wilmington, Delaware 19898	Nonwoven polypropylene
Bay Mills 196-380-000	Bay Mills Midland Limited Postal Code L-4R-4GI Midland, Ontario Canada	Woven fiberglass

STRENGTHENING

The presence of a fabric between two soil layers can effectively strengthen a pavement system by resisting the stresses imposed in the pavement by loads applied to the pavement surface. The various opinions as to how the strengthening actually occurs are discussed in the paragraph DESIGN PROCEDURES. This strengthening effect can permit the use of a thinner section above the soft soil than would be required without the fabric.

PERMEABLE SOIL BARRIER

The pore size distribution of the fabric permits the fabric to serve as a permeable soil barrier in that the fabric allows moisture to migrate into the base or subbase while preventing the subgrade fines from migrating into the base or subbase. Should the fines collect in the base or subbase, then the strength of the base or subbase would be reduced. The fabric therefore serves as a barrier to the effects of pumping and also reduces pore pressures. This aspect of the use of fabric is discussed in Reference 1.

FACTORS INFLUENCING PERFORMANCE OF FABRIC-REINFORCED PAVEMENT

Those factors affecting the performance of a fabric-reinforced pavement include the normal pavement design parameters in addition to the fabric properties.

NORMAL PAVEMENT DESIGN PARAMETERS

Thickness. The thickness of pavement consists of the material placed above the subgrade and includes any select material, subbase, base, or surface course (asphalt or concrete).

Subgrade Strength. The strength of the subgrade is important as it affects the thickness of material to be placed in the pavement since the weaker subgrade requires the thicker pavement. However, the very soft soils can limit the thickness of material that can be placed because of the settlement that may occur under the weight of overburden placed on the subgrade.

Load. The weight of the vehicle using a pavement also interacts with the subgrade strength to affect thickness. For airport pavement design, the controlling load affecting the subgrade is usually the aircraft gross weight although wheel loads and landing gear geometry are also important.

Traffic. The amount of traffic also affects pavement design, since the number of repetitions of a load must be considered.

Flexural Strength. For a concrete pavement, the strength of the concrete is an additional parameter influencing pavement design.

FABRIC PROPERTIES AFFECTING PERFORMANCE

Tensile Strength of Fabric. The tensile strength of the fabric is important when the fabric serves as a reinforcement. As a pavement system deforms, the fabric also deforms, thereby inducing tensile stresses in the fabric. The fabric must have sufficient tensile strength to resist these stresses.

Fatigue. Fatigue results from the application of repetitive loads that result in a loss of strength in the fabric. The number of repetitions of stress in the fabric could be very large depending upon the amount of traffic applied to the pavement.

Tear Resistance. Once a hole or tear has been introduced into a fabric, the resistance of the fabric to the spreading of the damage is its tear resistance.

Puncture Resistance. A fabric located between a granular material and the subgrade is subject to puncture by the granular material due to the action of loads moving the aggregate. This movement could be downward by individual rocks that could penetrate the fabric. The ability of the fabric to resist penetration is its puncture resistance.

Burst Strength. The ability to resist stresses applied uniformly over a large area and in all directions is the burst strength of the fabric. This is a special case of the tensile type of failure.

Abrasion Resistance. The elastic deflection of the pavement under repetitive loadings could cause the fabric to be subjected to abrasive action by the aggregate above the fabric.

Friction. Friction develops between the fabric and the subgrade, the fabric and the overlying layer, and the fabric and the overlapped fabric at the joints. This friction restrains the movement of the fabric and helps activate the tensile strength of the fabric.

Elongation. Elongation may be due to the reorientation of the fibers in a fabric when stressed or due to the stretching of the fibers. Increased elongation reduces the amount of stress in the fabric and thereby the effectiveness of the fabric as a reinforcement.

Creep. The strain that develops in a fabric under constant stress is creep. Fabrics that are prone to creep will show relaxation of stress. A reduction of stress in the fabric will cause the subgrade stress to increase, thereby reducing the effectiveness of the fabric.

FACTORS INFLUENCING PERFORMANCE OF FABRIC USED AS SEPARATOR

The above paragraphs described factors that affect the performance of a fabric-reinforced pavement. Fabric properties that affect the performance of the fabric when used as a separator include tensile strength, fatigue, tear resistance, puncture resistance, burst strength, abrasion resistance, elongation, creep, and friction. The size and shape of the soil or granular layers would also influence the performance. Sharp, angular aggregate would be more prone to damage the fabric and permit mixing with the subgrade than would rounded aggregate. The filtration characteristics of the fabric would also influence the performance.[1]

FAILURE MODE

The most common mode of failure of a pavement is the rutting of the pavement surface as a result of densification of the pavement layers or as a result of shear deformation. The application of traffic to a pavement continues to compact the layers of a pavement. This densification may be large or small depending upon the amount of compaction built into the pavement system. Should this densification occur in the layers above the fabric, the fabric would not be helpful in reducing

the rutting. However, should the densification occur in the subgrade, the tensile strength of the fabric would be activated and the amount of deformation reduced.

Deformation of the pavement surface due to shear occurring in the soil layers of the pavement will be reduced if the fabric is located so as to intercept the shear plane. Movement of the soil outward from under the load would place the fabric in tension and therefore resist the soil movement.

Repeated deflection of the pavement may cause a fatigue-type failure of the pavement. The elastic deflections will probably occur regardless of the presence of a fabric since the fabrics will not have the stiffness necessary to resist the elastic deflections.

Failure of a pavement could also result from the inability of the fabric to fulfill its role as a separator. Tears in the fabric or openings that are too large could allow the fines and granular material to mix, causing a weakening of the structure and an early failure.

FABRIC TEST PROCEDURES[2]

Several test methods are available for the testing of fabrics. The majority of these tests were developed for measuring the properties of fabrics that were to be used for other than reinforcement or separation. Those properties considered important to the performance of fabrics over soft soils are shown below along with the test procedures used by most manufacturers to measure each property.

Fabric Property	Test Procedures
Abrasion resistance	ASTM D 1175
Burst strength	ASTM D 751, D 213
Creep	ASTM D 2990
Elongation	ASTM D 1682
Fatigue	ASTM D 885
Friction	ASTM D 3334
Modulus	ASTM D 1682
Puncture resistance	ASTM D 751
Tear resistance	ASTM D 2263, D 1117
Tensile strength	ASTM D 1682
Thickness	ASTM D 1777
Weight	ASTM D 1910

The use of these test methods is generally accepted although tests for such properties as creep, fatigue, and friction could be improved to better represent the performance of the fabric within the pavement.

FABRIC EXPERIENCE

Experiences in the use of fabrics have encompassed laboratory tests, prototype tests, and field installations.[3-28] The laboratory and prototype tests have consisted primarily of constructing a soil-fabric system and loading that system to ascertain the improvement provided by the fabric in load-carrying ability and to explain why the improvements took place. These tests have consisted of small-scale and full-scale tests. The different types of fabric experiences are discussed below.

PLATE BEARING TESTS

Numerous investigators[3,4] have conducted plate bearing tests on laboratory-constructed soil-fabric-aggregate systems. These tests have been conducted in different modes, using a range of plate sizes, thicknesses of aggregate, static loads, and both repeated loadings and vibratory loadings. These tests have generally indicated improved performance of pavements containing fabrics when compared with an equivalent pavement without a fabric. However, there were some tests that showed very little, if any, improvement in the pavement performance using fabrics. In these cases, the investigators agreed that the tensile strength had not been activated because of small deformations. In addition, many of the investigators pointed out that a major advantage of using fabrics is that the fabric prevents the mixing of the fines with the aggregate.

LABORATORY TESTS OF FABRICS

Numerous tests have been conducted by manufacturers on their fabrics, and the results reported in their literature. These results point out the variability of fabrics available for use and show that the properties of the various fabrics cover a wide spectrum of values. In addition, investigators have conducted special tests on fabrics to determine their suitability for use over soft soils.

Haliburton, Anglin, and Lawmaster[5] conducted tests on 28 fabrics to determine their suitability for use over soft soil on which an embankment was to be built. All fabrics were subjected to tension tests, and those meeting special requirements were subjected to additional tests for determination of creep, frictional resistance, and effects of immersion and water absorption on development of tensile strength. The tensile strength of four of these fabrics at 10 percent strain exceeded 100 lb/in. (17.51 kN/m) of width; two fabrics were between 50 and 100 lb/in. (8.76 and 17.51 kN/m); seven fabrics were between 25 and 50 lb/in. (4.38 and 8.76 kN/m); and the others were below 25 lb/in. (4.38 kN/m).

Vollor[6] investigated the usefulness of new test methods being developed by other researchers and test methods commonly being used to assess the physical properties of fabrics for geotechnical use. Research was limited to tests for properties in which the force was within the plane of the fabric, with emphasis on load versus elongation. Those methods studied were the 2-in.- (5.08-cm-) wide cut strip test (ASTM D 1682[3]), Capstan LVDT test (presented by Vollor[6]), and the plane strain tensile test (developed by Sissons[7]). This study indicated that the elongation at break obtained by the cut strip test was not accurate because of slippage of the fabric in the jaws during testing. The results of the Capstan test indicated that it can give accurate load versus elongation results for woven fabrics but needs major modification to test nonwoven fabrics. The plane strain test method using wooden brackets proved to be a workable test method, but it needs modification to restrict or eliminate the effect of pins on the breaking strength.

PROTOTYPE TESTS

Prototype testing refers to the construction of a full-scale test pavement and loading that pavement in a manner similar to that which would be experienced by a typical pavement. This type of testing demonstrates the effectiveness of the fabric in improving the performance of the pavement.

The U. S. Army Engineer Waterways Experiment Station (WES) has conducted prototype tests of soil-fabric systems that relate directly

to the use of fabrics in pavements on soft soils.[8] These tests consisted of trafficking three test items with a 5-ton (4.53-metric ton) dump truck. The test items consisted of 14 in. (35.56 cm) of crushed stone on a military T-16 membrane (neoprene-coated nylon fabric) and on a nonwoven fabric and 14 in. (35.56 cm) of crushed stone placed directly on the subgrade as a control item (no fabric). The results of these tests indicated that the placement of the fabric between the soft subgrade and the crushed stone offered benefits in terms of an increase in load repetitions, which may be translated into a reduced thickness design. This improvement resulted from the fabric providing separation and tensile reinforcement.

The WES has also conducted many other type traffic tests using fabric membranes to improve the pavement system. Although not specifically related to the use of fabric over soft soils, they do show some of the benefits that can be derived from the use of fabrics. These tests have consisted of using fabrics as a surfacing material on runways, helicopter landing pads, and roads to provide an all-weather facility.[9-12] These fabrics were coated with materials to provide a waterproof membrane. Other fabric tests have consisted of using fabrics to construct membrane-encapsulated soil layers (MESL) for use in a pavement system.[13-15] The MESL provides a means of using low-quality soils in pavements by wrapping them with fabrics and keeping them dry.

The U. S. Forest Service has also been active in this area and has conducted several tests in which fabrics were placed over a muskeg subgrade and overlaid with granular material. These tests were conducted on roadways for use by logging vehicles. One test section[16] was located in the Tongass National Forest, Alaska, consisting of a muskeg subgrade, a Fibertex fabric, and aggregate. The test section was instrumented to provide measurements of strain in the fabric and settlement of the granular fill material. Thicknesses of the granular fill material varied from 3 to 8 ft (0.91 to 2.44 m). The thicker sections were needed where fabric was not used, and the thinner sections, where fabric was used. The use of fabric reduced the required thickness of granular material by an average of 28 percent. Another test section[17]

was located in the Quinalt National Forest, Washington. The test sections were designed according to the design procedure presented by Steward et al.[18] Instrumentation of the items included settlement plates, pressure cells, and strain gages. Results of these measurements showed that settlement in the test section occurred rapidly up to about 6 in. (15.24 cm) and that the strain gages measured no strain in the fabric after being trafficked by logging vehicles. The absence of strain indicates that the fabric was performing as a separator without contributing to the strength, although with additional traffic some strain may occur.

Prototype tests have also been conducted by Brown[19] and by Brantman et al.,[20] although the results are not yet available.

CONSTRUCTION PROJECTS USING FABRICS

Numerous projects have been constructed that made use of fabrics. These projects have consisted of airfields, roads, parking areas, etc. Most of these projects as reported in the literature are presented from the standpoint of construction and not performance. Therefore, it is difficult to know where the problem areas exist as far as long-range performance is concerned. Several of those projects where fabrics have been used in constructing pavements over soft soils are reported below. These projects point out some of the different ways in which fabric has been used in pavements.

Jacksonville Airport[21]. Fabric was used under a runway at the Jacksonville International Airport, Jacksonville, Florida, primarily for the purpose of separation. The pavement consisted of 14 in. (35.56 cm) of portland cement concrete (PCC) pavement, 6 in. (15.24 cm) of Econocrete base, and 6 in. (15.24 cm) of subbase placed on top of a lightweight fabric. This fabric has been in place for over two years and seems to be performing satisfactorily. Other areas at the airport are to be constructed using the same technique.

Saline County, Arkansas[22]. A thin layer of aggregate was placed over a fabric on a county road, and some difficulty was encountered during construction. The thin layer of aggregate (thickness not

reported) was not sufficient, and the construction equipment damaged the fabric. This required repair of the fabric in many instances.

Conway County, Arkansas[22]. From 18 to 20 in. (45.72 to 50.8 cm) of aggregate were placed over a fabric on a county road without any significant construction problems. One problem that did occur was that mud trapped below the fabric by the freeze-thaw cycles erupted through the fabric to the surface of the aggregate. Thus, some slack was permitted in the fabric to prevent this type action happening again.

Kinlock, Missouri[23]. A fabric was placed on the subgrade, and the paving directly on top of the fabric. This fabric was placed to provide reinforcement and reduce the required thickness of material over the subgrade. This project was constructed in 1977 and has performed well.

Carrollton, Texas[24]. Engineers on this project elected to use fabric in construction of a road rather than lime stabilization, which was the normal procedure. The fabric was placed on the subgrade and covered with 12 in. (30.48 cm) of aggregate. The aggregate was dumped with the trucks maneuvering on the fabric with no apparent damage to the fabric. The compacted depth of aggregate is 10 in. (2.54 cm) and is to be surfaced with asphalt. The performance of the fabric section is to be compared with an adjacent section of road on which a lime-stabilized subgrade was used.

Venice, Louisiana[25]. Fabric was used to construct access roads and a storage area for trucks weighing up to 90,000 lb (40.82 metric tons). These areas were constructed by placing 6 in. (15.24 cm) of shell on the soft subgrade, laying the fabric on top of the shell, and then placing another 6 to 8 in. (15.24 to 20.32 cm) of shell on top of the fabric. This provided a much more suitable area than was previously provided by 18 in. (45.72 cm) of shell on the subgrade.

Booneville, Indiana[25]. An 8-in. (20.32-cm) thickness of aggregate on a soft clay soil was being rutted by coal trucks and required significant maintenance. Upon deciding to use fabric on this road, additional aggregate was added to the road and graded smooth. Fabric was then laid down, and an additional 8 in. (20.32 cm) of aggregate placed

on top of the fabric. Rutting has ceased, and the road seems to be performing satisfactorily.

DESIGN PROCEDURES

The development of a complete design procedure for use of fabric over soft soil has not yet been accomplished, although several methods have been proposed. These show promise but have not been adequately validated through field performance.

KINNEY AND BARENBERG[26]

Kinney and Barenberg present three basic mechanisms by which fabrics may change the response characteristics of a pavement. The first mechanism involves the direct stress on the fabric. When the subgrade-base interface is deformed, the fabric is put into tension. This tension causes normal stresses on the soil as the fabric curves around the bottom of the base. These stresses tend to spread the load.

The second mechanism involves a change in the material properties of the base by changing the stresses in the base. A small increase in the minimum principal stress will increase the elastic modulus of the base. This increase in stiffness will allow the load to be distributed over a wider area. A modulus increase will also decrease the permanent deformation potential of the base.

The third mechanism can be likened to tensile reinforcement in concrete. The tension member at the bottom of the granular layer allows the layer to carry some moments, thereby causing a slab-like action that redistributes the stresses and stiffens the pavement system.

The first mechanism of failure dealing with the normal stress on the fabric was treated in detail in order to explain the performance of two fabrics that had been tested under prototype conditions. Several possible cases, which involved no slippage of the fabric, interior slippage, and progressive slippage, were investigated to support this failure mechanism.

The techniques used in evaluating test data could perhaps be used to develop a design procedure for use of fabrics in pavements.

BARENBERG, DOWLAND, AND HALES[4]

Barenberg, Dowland, and Hales developed a design procedure from a combination of theoretical and laboratory test results and verified it by comparing the design thicknesses with results from field observations. Existing mathematical models were evaluated to select those applicable to this problem. Physical models of soil-fabric-aggregate systems were tested under repeated plate loads to obtain a better understanding of these systems and provide data with which to validate the mathematical models. The vane shear, CBR (California Bearing Ratio), and cone index were correlated to provide strength input into the system. In conducting tests, the soil-aggregate system was tested with and without fabric to provide an indication of the benefits of the fabric. The mathematical model[27] selected for the design procedure was used to predict the depth of rutting in soft, fine-grained soils due to traffic of wheeled vehicles. Bearing capacity formulas were used to determine the allowable stress on a soft soil. The Boussinesq theory was then used to calculate the depth of cover required to prevent the applied load from exceeding the allowable stress. From these calculations, it is possible to relate the depth of pavement required for a given load to the strength of the subgrade for a pavement with and without fabric.

It should be pointed out that this procedure was developed using tests on a specific fabric to validate a mathematical model. This would require that bearing capacity factors be developed for other fabrics or the system be validated for other fabrics.

BROWN[19]

Brown presents an analytical approach to quantify the effects of fabrics on a pavement system using layered-elastic analysis. One purpose of using fabric in the pavement is to serve as a reinforcement to the pavement structure. This analysis indicated that the fabric layer made no significant change in the calculated stresses or strains in the structure and therefore seemed ineffective as a direct reinforcement.

however, it was indicated that experimental data are needed to resolve the question of whether the theory correctly models the real situation.

A primary benefit of the fabric was the possible influence that the fabric may have by way of stiffening the granular layer above the fabric. Brown discussed a theoretical analysis using finite element techniques performed by Thompson[28] to examine this possibility. The fabric was considered to act as a reinforcement to sustain tensile stresses at the bottom of the granular layer. This reinforcement increases the effective modulus of the granular layer. It was indicated that the ratio of the modulus of the granular layer to the soil layer may be increased by as much as 3.0.

CONSTRUCTION

The procedure for constructing airfield-type pavements is to initially remove all sharp or large objects and rough grade where necessary to fill ruts or other irregularities. Grasses or vegetative root mat may be left in place. The fabric is then rolled onto the subgrade in the direction parallel to traffic. Rolls of fabric placed side by side must be properly joined by overlapping, sewing, bonding, or welding. The overlying material is then placed by end-dumping and spreading with a bulldozer or other similar equipment. When placing material, care should be taken to ensure that vehicles do not traffic directly on the fabric. Also, end-dumping of aggregate directly on the fabric could possibly damage the fabric; therefore, when this may occur, the most appropriate procedure for the placement of overlying material is to dump the material off the fabric and then use proper equipment to spread the material.

CONCLUSIONS

Although the use of fabrics in pavements is relatively new in the technology, it does show promise for use in constructing airfield pavements over soft soils. The fabric can serve as a separator to protect a granular layer placed on the subgrade and as a reinforcement to provide thickness reductions and strengthen the pavement structure. In addition, the fabric may be helpful in frost areas by separating nonfrost-susceptible soils from frost-susceptible soils. However, in order to provide an adequate design criterion, several items need to be developed:

- a. An appropriate thickness design procedure that considers the most important characteristics of fabrics in relationship with conventional pavement design parameters.
- b. Test methods that adequately describe the characteristics of fabrics that are important in pavement design.
- c. The mechanisms by which fabrics improve the performance of pavements, and appropriate descriptions of fabric performance.
- d. Specifications for use of fabrics in pavements that set limits on fabric properties necessary to fulfill design requirements.

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